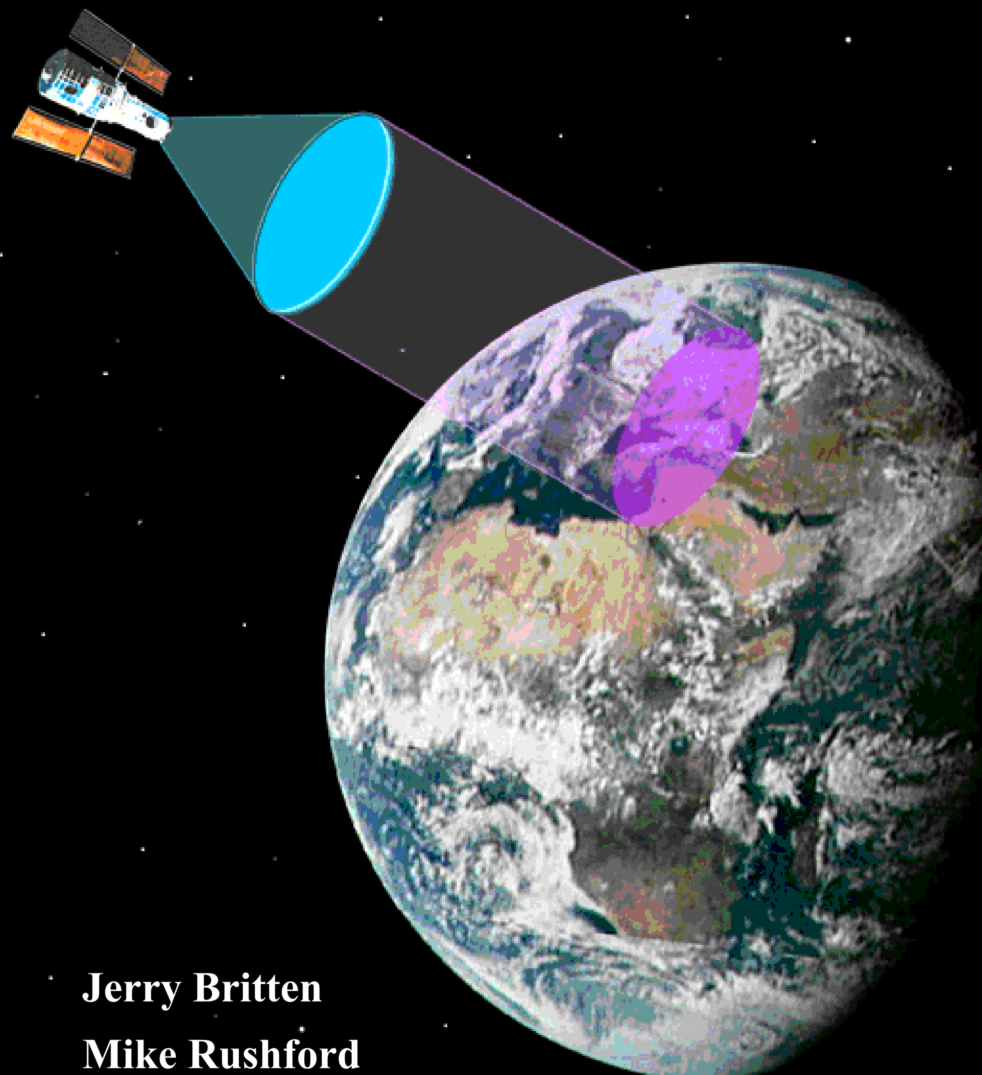
A Gossamer Fresnel Lens For Space-based Imaging



Surveillance

Defense

Astronomy

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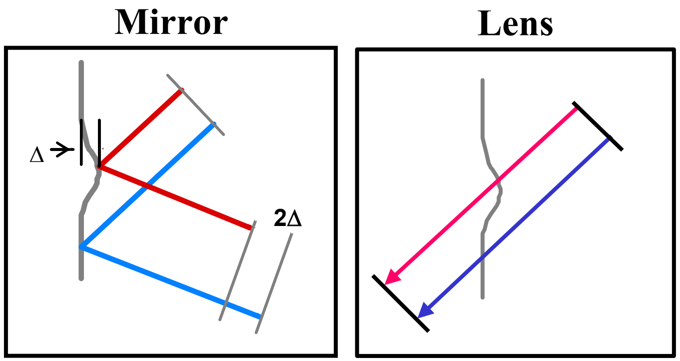
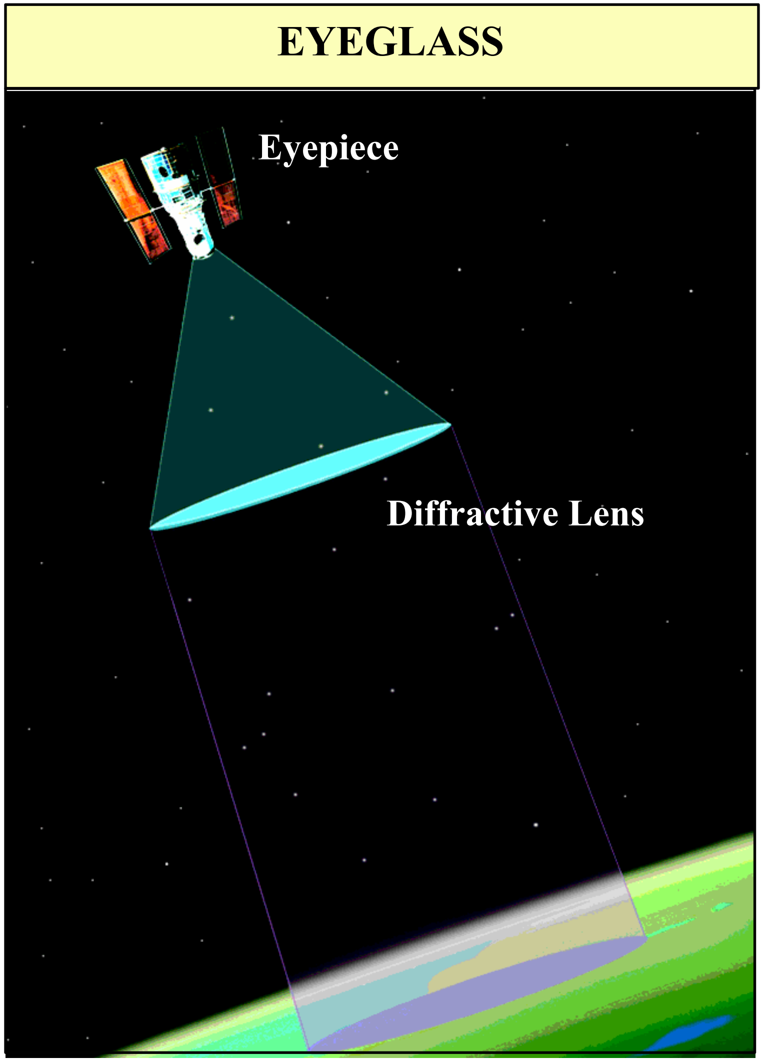
Eyeglass is a New Type of Large Space Telescope

- Large diffractive lens ⇒ Two major advantages
  - Optical tolerances : Aperture is slow, transmissive lens
    - Tolerates much larger ripples (> 40,000) than mirror



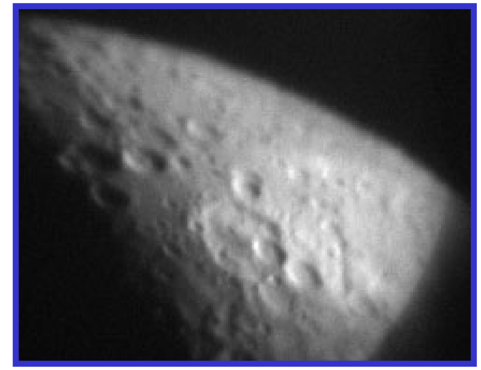
  - Fielding : Aperture is thin, flat membrane
    - Thin : Lightweight, flexible, and packageable
    - Flat : Easy to package, deploy, and hold in-shape

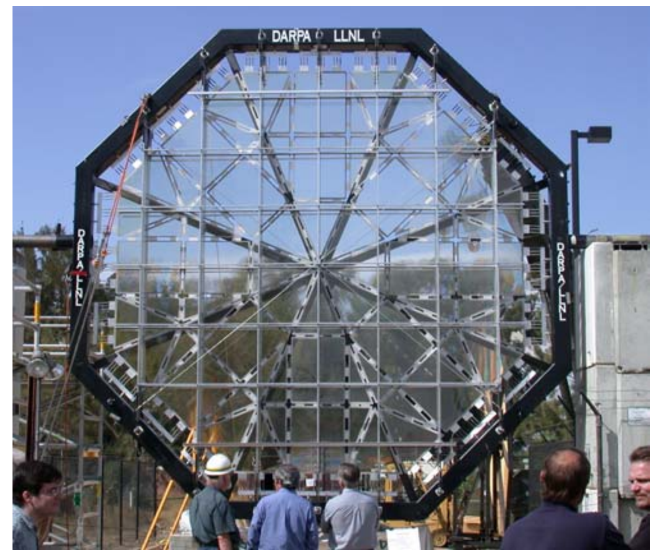


- Telescope contains two cooperating spacecraft
  - Main Aperture : Thin diffractive lens
    - Low mass and loose tolerances
  - Eyepiece : Mobile image collector
    - Conventional (meter-class) telescope and vehicle
  - Stationkeeping : Vehicles stay ~ kilometer apart
    - Micro-gee propulsion with slow, loose, control loop

Eyeglass : Challenges and Progress

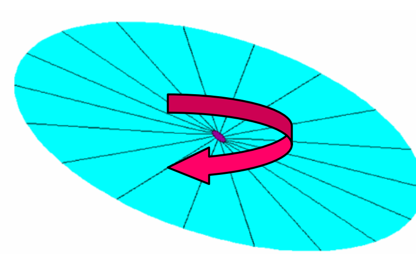
- Color Correction
  - Challenge : Diffractive optics are usually monochromatic
  - Progress : We have built and tested broadband telescopes
    - Diffraction-limited from 470-700 nm
    - And have *really* broadband designs : Visible ⇔ LWIR



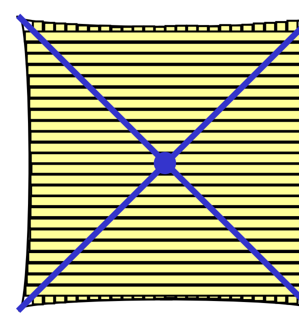


- Fabrication
  - Challenge : Need large (tens of meters) diffractive lens
    - Using thin, space-suitable, materials
  - Progress : We have built a thin, 5 meter, glass lens
    - Have patterned thin, space-suitable, polymers

- Space Fielding
  - Challenge : Lens must be stowed and launched
    - Then deployed, held-in-shape, and used in space
  - Progress : We have designed large telescopes
  - With ways to package, launch, and deploy them

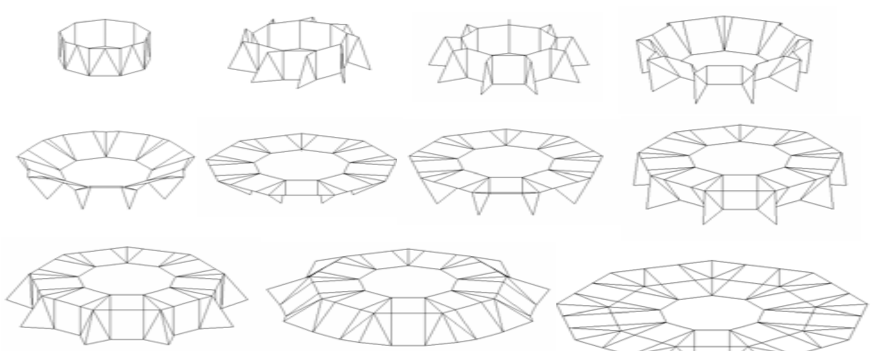


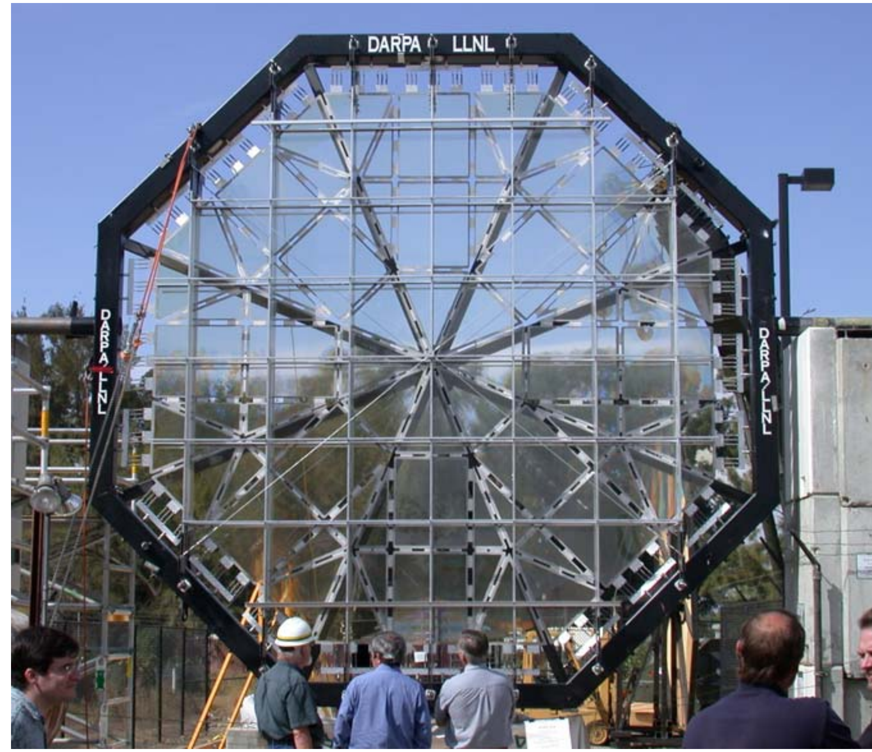
or



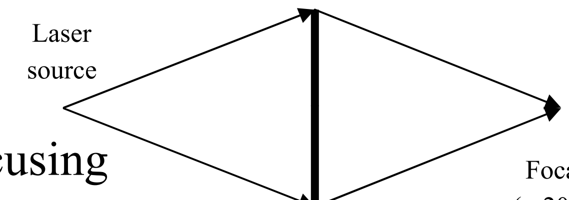
We Have Built a 5 meter Lens : LLNL & DARPA

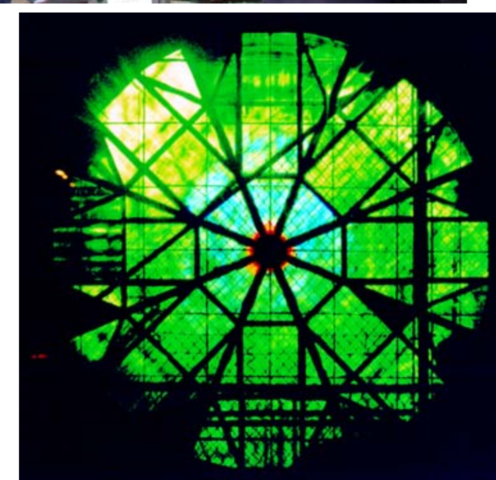
- Palomar-sized diffractive lens
  - Lithographically patterned : *f* / 50
    - Binary phase profile : 60 μm period
  - 72 thin-glass panels : 70 x 80 cm
    - 700 μm thick : 1.6 kg/m^2
  - Arranged in foldable pattern
    - Origami-fold to octagonal hatbox





- Optical demonstration
  - Point-to-point (200 m) focusing
  - Used green, red, violet lasers
  - Got tight (1-2 cm) spots
    - Set by turbulence, unsmoothed glass





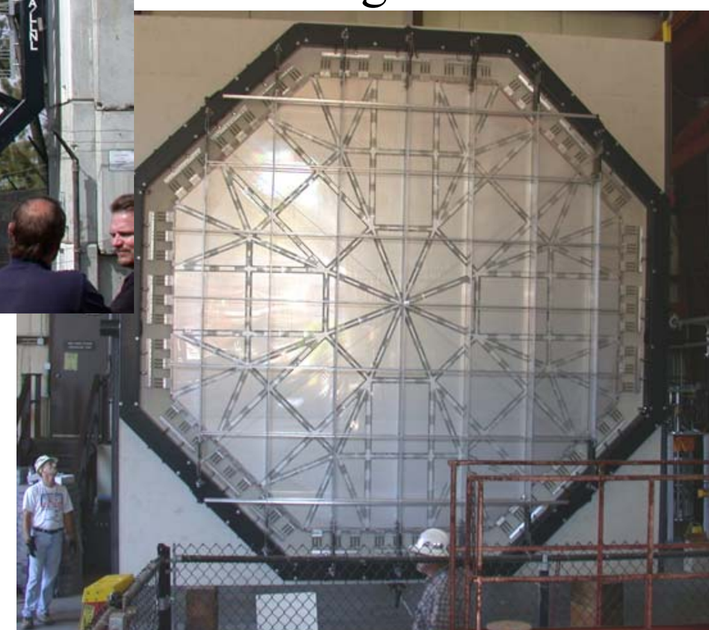
View from green focus

The Lens Was Built in 100 Days

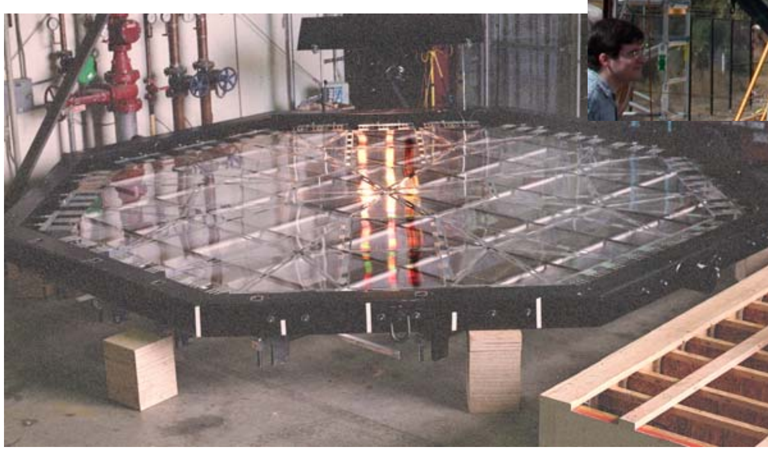
1: Lithographic Masks

2: Assembled Lens

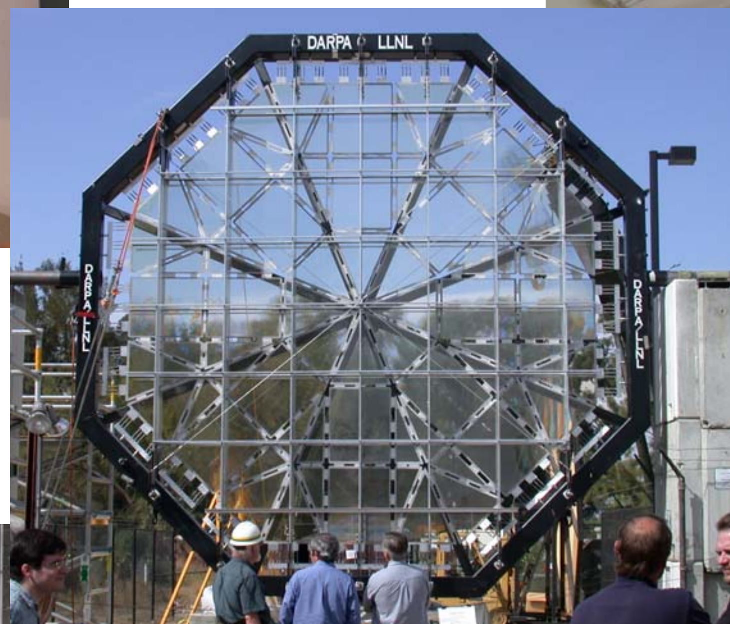
3: Being Mounted



4: In the Lab

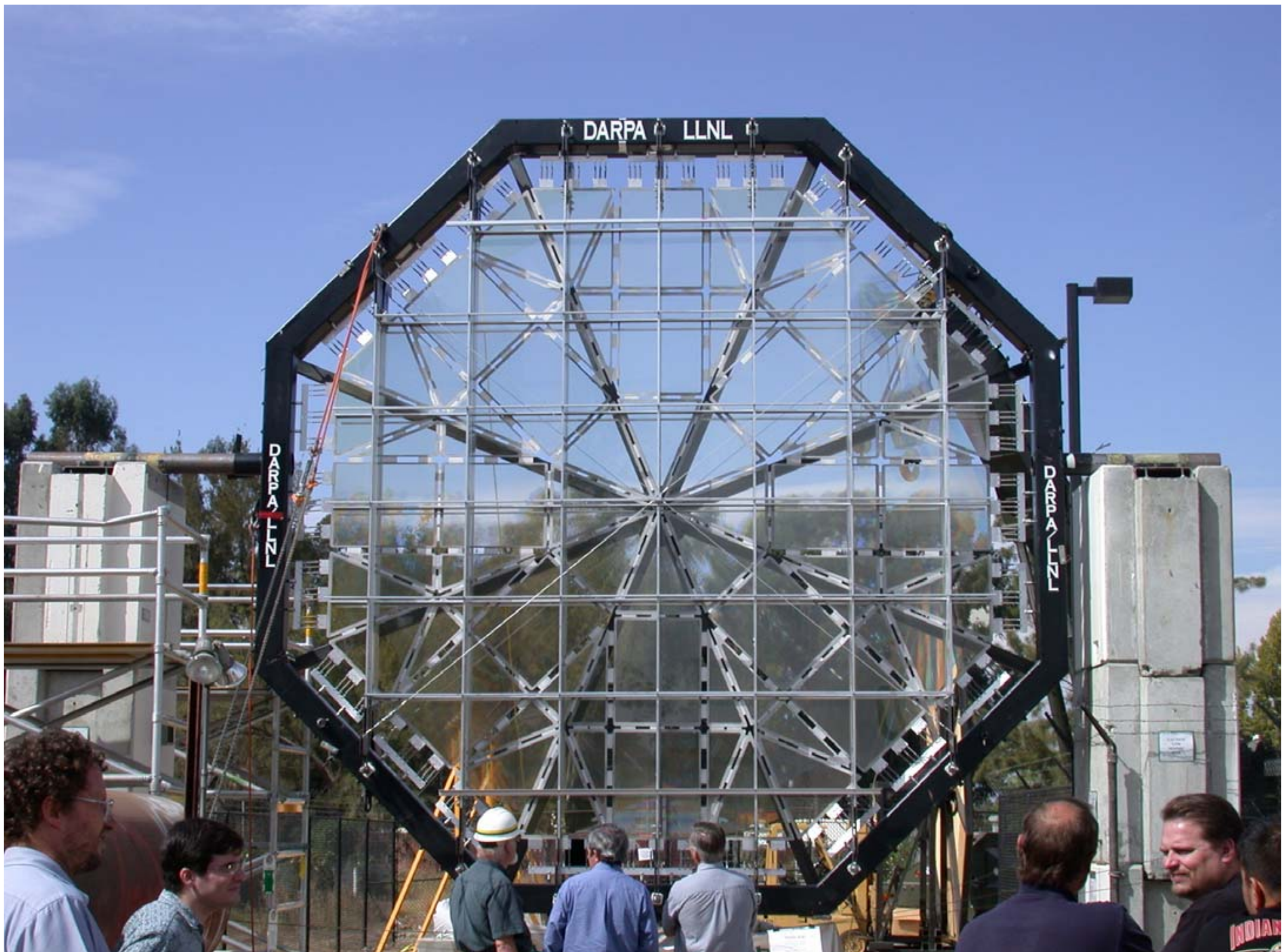


5: In the Field



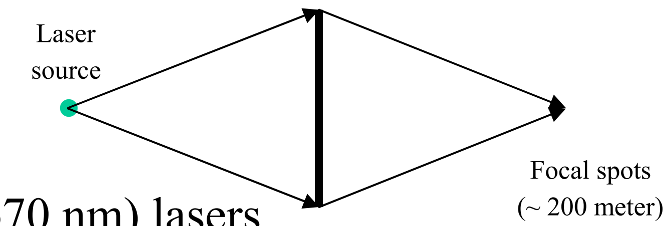
Five Meter Lens in the Field

- Palomar-sized diffractive lens
  - Made with 72 separate thin-glass (0.7 mm) segments
  - 250 meter focal length utilizing 60 μm wide grooves

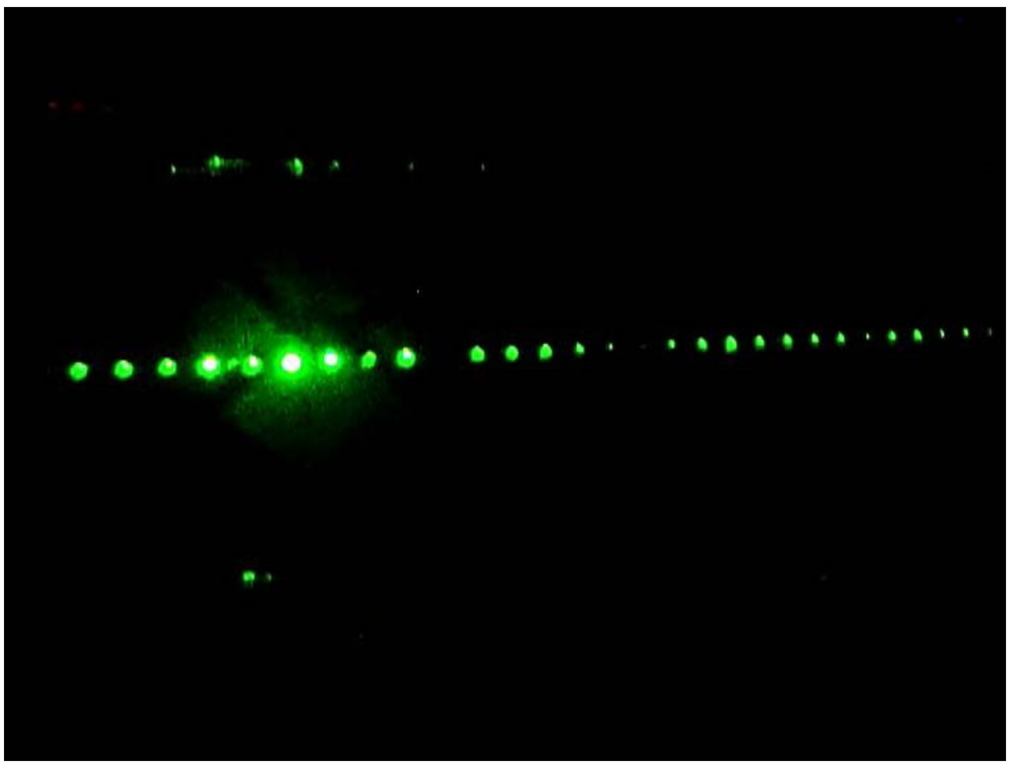


5 Meter Lens : Optical Performance

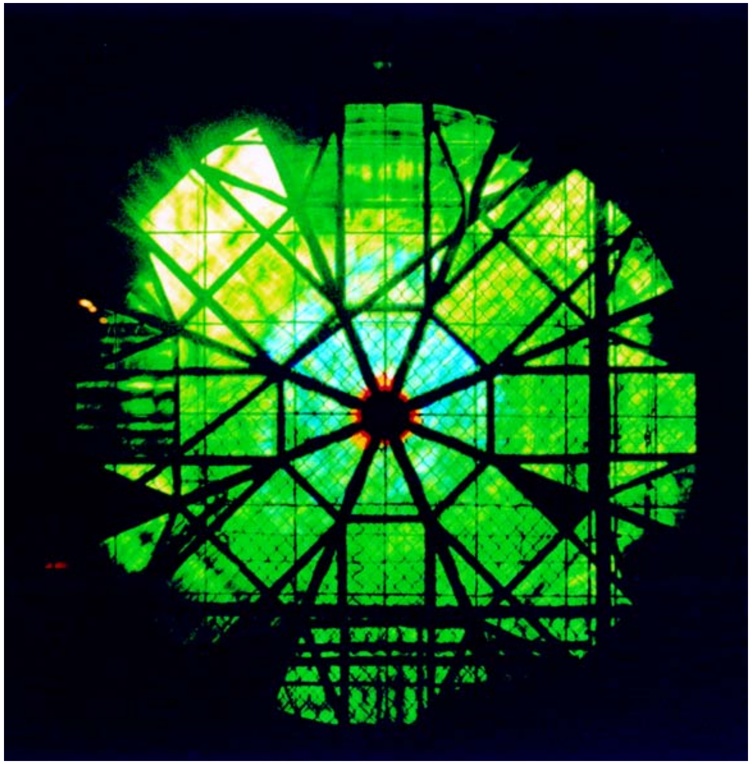
- Point-to-point tests
  - Expand point source to fill lens; Then refocus to spot(s)
  - Tested with purple (405 nm), green (532 nm), and red (670 nm) lasers



Delivers multiple (1-2 cm) focal spots: Set by atmosphere and glass-nonuniformity



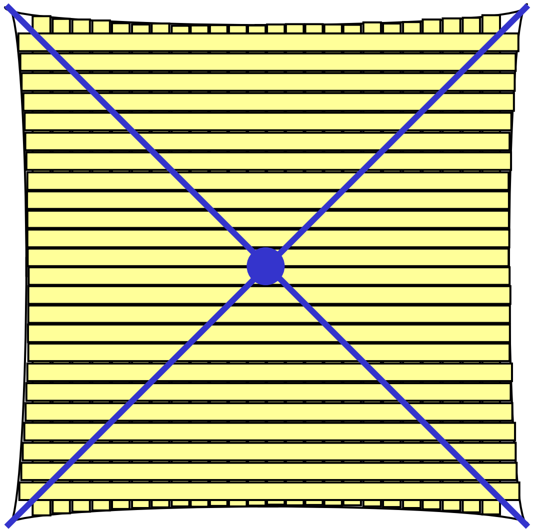
String of harmonic focal spots



Back-view from one focal spot

Eyeglass : Future Directions

- Polymer Lenses
  - Large lenses must be thin and lightweight
    - 1 mil polymer films vs. 700 µm glass sheets : 50-fold improvement
  - Easier to launch than glass
    - Plastic may crease, but it won’t break
  - Use space-suitable polyimides
    - Kapton (the standard), CP1 (transparent), TFDB (transparent & low CTE)
  - Examine two, roll-to-roll, commercial patterning processes
    - Laser ablation : Inkjet nozzles, Chip dielectric layers
    - Micro-embossing : Hologram coatings



- Square Ribbon Lens
  - Two orthogonal arrays of ribbons
    - Crossed 1-D lenses : Each ribbon focuses light in one direction
    - Loose tolerances : Distortions along ribbon length have no effect
  - Launchable and deployable
    - Ribbons are individually packaged in meter-width rolls
    - Mounted on deployable truss and pulled-out like window-shades